Voice assimilation

The case of Greek /s/-voicing and the phonetics-phonology interface

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Abstract

Assimilation phenomena often attract phonologists' interest, as they are common in every language. However, various assimilation phenomena remain unstudied, especially in terms of experimental phonology and phonetics. One of the most common cases is /s/-voicing in Standard Modern Greek (SMG), i.e. the conversion of a voiceless [s] to a voiced /z/ when followed by a voiced consonant as a result of regressive voice assimilation. Most of the previous research indicates variability across speakers and across different types of consonants. Overall, the realization of /s/-voicing is described as gradient rather than categorical. Previous studies have only focused on /s/-voicing across word boundaries. However, /s/-voicing also occurs within the boundaries of a word. In many cases, clusters containing a sibilant and a voiced consonant are formed by morphological processes. This study aims to investigate the /s/-voicing across word boundaries, morpheme boundaries, and stem internally in order to describe the application of /s/-voicing in SMG in different morphological environments. For the goals of this study, native speakers of SMG were recorded during a production experiment. The speakers read aloud a number of passages designed to contain different cases of /s/-voicing. Various acoustic correlates were examined in order to describe the tokens phonetically and compare the assimilated tokens with the sibilant phonemes /s/ and /z/ of SMG. The applicaiton of voicing was measured as the ratio of the voiced part of over the total duration of the sibilant. The different morphological boundaries did not seem to affect the application of /s/-voicing. However, the voicing ratio differs across the different types of following consonants as well as across speakers. These results confirm the previous literature in regard to the effect of the following consonant and between-speaker variability. The center of gravity was the most distinctive characteristic between assimilated and non-assimilated tokens and differences in terms of duration and intensity were found between the non-assimilated and [s] tokens as well as between assimilated and [z] tokens.

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Contents

1 Introduction

In Standard Modern Greek (SMG) /s/-voicing is a well-documented phonological rule of regressive assimilation (Horrocks 1997). According to this rule, the voiceless phoneme [s] becomes voiced /z/ before voiced consonants.

(1) σύνδεσμος connection ['sinðezmos]

This assimilation phenomenon has only recently been studied phonetically (Arvaniti and Pelekanou 2002; Tserdanelis 2005; Baltazani 2006) and these studies have focused on the realization of the phenomenon across word boundaries, that is, when a word ends with a [s] and the following word begins with a voiced consonant. In this study we aim to investigate /s/-voicing in all the possible environments, that is, both word internally and across word boundaries as well as in different segmental environments using different types of voiced consonants. In this study we aim to focus on two factors and examine whether they affect the realization of /s/-voicing: a) the boundary depth, by examining $/s/ + C_{[+voi]}$ clusters in the stem, across morpheme boundaries and across word boundaries based on morpheme-based morphological approach (Ralli 2003) and b) the type of the following consonant, using voiced plosives, fricatives, nasals and sonorants in $/s/ + C_{[+voi]}$ clusters. Previous literature has shown that the following consonant affects the realization of /s/-voicing as well as that speakers differ in the degree in which they apply /s/-voicing. We aim to re-examine this parameter as well. Native speakers of SMG were recorded reading texts that were created for this study and contain different cases of $/s/ + C_{[+voi]}$ clusters. The data were analyzed phonetically and several acoustic characteristics were measured, such as the duration and voicing of the token in order to describe the realization of /s/-voicing.

This thesis is structured as follows: In the first section (1.1) we will examine the nature of assimilation phenomena in general. There has been a lot of research on the different types of assimilation cross-linguistically. In the next section (1.2) we will give a brief overview of the studies that focus on a phonological analysis of assimilation. In the section (1.3) we will discuss the case of /s/-voicing in Greek by reviewing the relevant literature and previous studies. In section (1.4) we will discuss how different phonological theories deal with idea of distinctive features and how these features can be described phonetically. Finally in the last section (1.5) I will try to give a description of the research approach that is being followed here and the main research question that we will try to investigate.

The second chapter describes the approach followed in the study and the research questions that we aim to answer, as well as the process and the material used for the production experiment. Chapter 3 provides the results of the experiment and a brief explanation of the findings of this study. Finally, Chapter 4 gives a more detailed discussion of the results and some general conclusions as well as the most important limitations of the study.

1.1 Assimilation phenomena: An introduction

Assimilation is one of the most common phonological phenomena across languages, which has attracted a lot of interest both from a phonological and a phonetic perspective. Bakovic (2007, 355) defines assimilation as the process whereby "two or more segments in a form agree in their value for some phonological feature(s) or feature class(es)". Apart from this general definition, more specific definitions have been proposed in the frame of specific theories.

Autosegmental Metrical (AM) phonology focuses on the features that constitute a sound, and considers these features as the lowest level of language organization (van Oostendorp 2011, 1). AM phonology also assumes that these features exist independently of each other, but are all attached to what we call "the skeleton, which keeps track of the time" (van Oostendorp 2011, 2). In terms of AM Phonology, assimilation is defined as the result of feature spreading (McCarthy 2011, 1). Articulatory Phonology tries to describe the processes as results of a sequence of gestures (Browman and Goldstein 1986; 1992). In terms of Articulatory Phonology, assimilation is the result of "gestural overlap" (1992, 29).

1.2 Cases of /s/-voicing across languages

A well-documented case of /s/-voicing occurs in several Italian dialects. Especially in Northern Italian, /s/ becomes voiced when it is found in intervocalic position (Krämer 2001, 1). However, there is lot of variability concerning intervocalic /s/-voicing across the Italian dialects. Intervocalic /s/-voicing is one of these phenomena realized in different degrees and different ways across Italian dialects (2001). The relation between an underlying unvoiced representation of /s/ and a surface voiced counterpart has been in question in a number of studies (Baroni 1998; van Oostendorp 1999; Krämer 2001; 2003). Baroni argues that in Northern Italian the voiced alveolar fricative can only occur in intervocalic position (Baroni 1998). According to Krämer "in OT, intervocalic s-voicing is captured as the effect of a high ranking markedness constraint" (2003, 4). Krämer then argues that dialects such as Tuscan and Lombardian, that is, those that apply /s/-voicing in intervocalic position, have different constraint rankings (2003, 4). Lombardian speakers retain markedness at a higher ranking than faithfulness whereas the reverse would be the case in Tuscan.

*VsV and faithfulness:

Initial stage:	MARKEDNESS	»	FAITHFULNESS (*VsV »IDENT(voice))
Tuscan:	IDENT(voice)	»	*VsV (achieved by demotion)
Lombardian:	*VsV	»	IDENT(voice) (= initial stage)

(Krämer 2003: 4)

Baroni investigated a different aspect of the intervocalic voicing in Italian, namely, the role of morphological environment in the application of voicing. Intervocalic voicing does not apply in specific cases, such as

recent loanwords (Baroni 1998, 1):

[asiˈmːɛtriko] "asymetrical"
[asosiˈale] "anti-social"

These examples represent a number of cases in which a /s/ in stem-initial position does not become voiced if preceded by a prefix-final vowel, although it is in intervocalic position. In his analysis, (Baroni 1998, 2) claims that: "the distribution of [s] and [z] is sensitive to morphological structure: intervocalic voicing is blocked when the vowel preceding /S/ does not belong to the same morpheme. I will refer to this phenomenon as Intervocalic Voicing Blocking (IVB)".

Another approach to the interface between Italian intervocalic /s/-voicing and morphological structure was followed by van Oostendorp (1999), who proposed that the prefixes can become part of the prosodic word of the stem in order to satisfy the Onset constraint. As the /s/-voicing occurs in cases where the preceding and following vowel belong to the same Phonological Word, cases such as [aso'sìale] can be explained by the fact that the initial syllable of the stem does not need to be incorporated in the same Phonological Word with the stem.

Baroni argues that intervocalic /s/-voicing in Italian dialects is categorical. His data analysis showed that only fully voiced or totally voiceless tokens were produced by the speakers, supporting his theory that /s/-voicing is a categorical rule and that there are cases in which voicing is blocked. Baroni's explanation of the categorical nature of this phenomenon is that "all the tokens of all the voiced categories (+z, z++, z) have a voiced portion / overall duration ratio of 1, i.e. there is no trace of devoicing, whereas even the most voiced voiceless token (the maximal value of the category +s) has a voiced portion/overall duration ratio of approximately 1/3 (the voiced portion of the voiceless tokens always occurs at the beginning)." (Baroni 1998, 5). We may consider this rule obligatory, since it applies always, while the realization of voicing seems rather gradual rather than categorical, as it applies in different degrees. We should also mention that the voiceless tokens did contain a voiced part in the beginning that can be supposed to be the voice tail, the vibration that continues into the next segment after a vowel (Berg 1986; Leander 2008). Grijzenhout (2000) examined voicing and devoicing phenomena in Germanic languages. A case of /s/-voicing can be found in English in the formation of the plural, e.g. dog → dogs. Since the feature in this case spreads to the next segment, it is a case of progressive voicing assimilation (Grijzenhout 2000, 5). Grijzenhout aims to provide an account within Correspondence Theory, according to which, assimilation phenomena follow a set of universal constraints and she argues that "differences between languages are explained by different constraint rankings" (Grijzenhout 2000, 5). An example of this relation between constraints can be the constraints AGREE and IDENT [voice]. The former constraint will lead to assimilation of the voiceless segment when followed by a voiced one, whereas the latter will prevent the assimilation in order for the segment to maintain its underlying value for the feature [voice]. Therefore, it depends on the ranking of these constraints whether assimilation will be applied or not and in which segmental environment. In Spanish we find cases of /s/-voicing before

voiced consonants both word-internally and across word boundaries (Schmidt and Willis 2011, 2):

después	[des.pwes]	'after'	(/s/ is not voiced)
desde	[dez.ðe]	'since'	(/s/ is voiced word-internally)
los bancos	[loz.βaŋ.kos]	'the banks'	(/s/ is voiced across word boundary)

Schmidt and Willis (2011) report different degrees of voicing in Mexican Spanish. Another case of intervocalic /s/-voicing, this time in Catalonian Spanish, has been investigated by McKinnon (2012). In his experiment, he tested sixteen speakers from Catalonia. His corpus consisted of recorded speech while the informants were reading aloud a text as well as of a short interview between the speakers and the researcher. Tokens from both recordings were used for the analysis. His data analysis focused on the percentage of voicing in the sibilant, using both the waveforms and the voice bar in the spectrogram as indicators for the presence of voicing. McKinnon categorizes the data in three groups according to the percentage of voicing: "tokens with 0% to 20% percent voicing were deemed 'voiceless'; 21% to 90% 'partially voiced'; and 91% to 100% 'fully voiced'." (McKinnon 2012, 19). The vast majority of the tokens that he examined were categorized as voiceless. A number of tokens were categorized as voiced and there were tokens also marked as "partially voiced" (2012, 22). These findings point to a gradient rather than categorical voicing since the rule does not apply in all cases and since it applies in different degrees. As McKinnon (2012, 23) argues, the results indicate that /s/-voicing in Catalonian Spanish "is not predictable; although certain (socio)linguistic contexts favor or disfavor it, /s/ is never exclusively voiceless or voiced in intervocalic position". In Schmidt & Willis (2011) and in McKinnon (2012) we find evidence indicating that the phonetic realization of /s/-voicing is not categorical and that assimilation may not apply in a number of tokens. We will focus more on the relation between the phonology of /s/-voicing and its phonetic realization in the next sections.

1.3 The case of /s/-voicing in Greek: Previous research

In Standard Modern Greek there are two sibilants i.e. an unvoiced [s] and a voiced [z]. When a sibilant is followed by a voiced consonant a voice assimilation process takes place and an underlying /s/ becomes [z] (Nespor and Vogel 1986). All the previous research on /s/-voicing in Greek focused on the realization of the phenomenon at the level of word boundaries, that is, in cases wherein the first word ends with /s/ and the following word begins with a voiced consonant. These cases have attracted a lot of interest because /s/-voicing across words was supposed to indicate shallow prosodic boundaries whereas blocking of voice assimilation revealed a deeper boundary (Nespor and Vogel 1986). The voiceless sibilant in written SMG is represented by the letter sigma (Σ, σ, ς) while the voiced one by the letter zeta (Z, ζ). The assimilation creates a mismatch between the written form and the pronunciation in these cases. When an underlying /s/ precedes a voiced consonant it will be pronounced as if there were a zeta in the written form, although there is a sigma, e.g.:

(2) άσμα ['azma] (song)

This mismatch between written and spoken form seems to be a result of the phonological development of Greek. In Ancient Greek zeta was representing a complex segment ([zd] or [dz]). The affricate was then simplified to [z], during the Hellenistic period, creating a mismatch between phonology and orthography (Horrocks 1997). Until then sigma was the only letter representing a sibilant, and it would become voiced when followed by a voiced consonant (Horrocks 1997, 170). Apart from the /s/-voicing within the stem, a very common case of /s/-voicing occurs in the formation of the mediopassive participle:

(3) κλείνω κλεισ + μένο κλεισμένο
['klino] [klis + 'meno] [kliz'meno]

The discussion concerning the segmentation of the formative -s- in the passive participle is still open: the -s- can be assumed either as part of the stem (resulting in an allomorph), or as an inflectional suffix demarcating the aspect. Ralli (2003, 94) provides strong arguments in favour of the view that there is a additional morphological stem ending in -s- stored along with the basic stem, i.e. the s-stem, that is combined with the morpheme –men(os), which forms the passive participle in Greek (Example 2). Moreover, Ralli (2003) provides an adequate description concerning the steps that have to be taken before /s/-voicing occurs. The outcome of this combination is an $/s/ + C_{[+voi]}$ cluster that results to the assimilation of the sibilant. These cases indicate an interaction between phonology and morphology since the addition of the suffix leads to the voicing of the sibilant. This is also clear in cases where a prefix is added in a word starting with a voiced consonant, like in the word προσγείωση (landing):

(4) προς + γείωση → προσγείωση
[pros + 'jiosi] → [proz'jiosi]

In this example there is an underlying form of the prefix «προς» [pros] that is followed by the voiced fricative /j/. The examples provided above give us a brief idea of the most common cases of /s/-voicing assimilation in SMG. So far we have seen that the /s/+voiced consonant clusters ($/s/ + C_{[+voi]}$) can occur in stem internal positions and also across morphemes, that is, when a prefix or a suffix attaches to the base and results in this cluster.

Arvaniti & Pelekanou (2002) were the first to attempt a phonetic examination of phonological rules in Greek, including /s/-voicing. Their corpus contained spontaneous speech and recorded data from speakers reading texts aloud and the voicing was defined impressionistically based on the spectrogram and the waveform.

Although voicing would be expected to apply without exception, their analysis showed fully voiced, partially voiced and totally unvoiced sibilants in different cases. All the tokens contained similar prosodic boundaries, indicating that the differences were not due to varying boundary strength. Unfortunately, this study, although useful, was based on a very small number of tokens; only nine cases of /s/-voicing were examined. However, the results were important as they indicate that, when tested phonetically, /s/-voicing does not seem obligatory and it appears as a gradient rather than categorical phenomenon.

In a more detailed study, Tserdanelis (2005) created ambiguous phrases in which there were $/s/ + C_{[+voi]}$ clusters across word boundaries. Using these ambiguous sentences, in which the meaning could change depending on the prosody, he recorded native speakers of Greek in order to test the relation between prosodic boundaries and /s/-voicing as a sandhi rule (Tserdanelis 2005, 51). His measurements included the total duration of the sibilant and the duration of voicing during it. The intonation of the utterances was annotated using GRToBI (Arvaniti and Baltazani 2000; 2000) and analyzed in order to take into account differences in the prosodic boundaries.

Tserdanelis observed the waveforms and spectrograms of the recordings in order to determine the voicing of /s/. He reports only fully voiced and voiceless segments and no cases of partially voiced tokens (2005, 77). He also reports that in the cases where there was a prosodic boundary, the assimilation was blocked and the sibilant was not voiced. Furthermore, according to his results voicing would apply always in cases with no prosodic breaking.

In the last study on /s/-voicing to be reviewed here, Baltazani (2006) tested the realization of /s/-voicing at word boundaries. To do so, she created a matrix sentence in which only one word would change in order to create different segmental environments, by putting different voiced consonants after the voiceless sibilant. The consonants used in her experiment are the three voiced obstruents of Greek [b, d, g] and the two sonorants [l, r]. In order to measure the degree of voicing she measured the total duration of the sibilants. She also measured the duration of voicing in each of them, based on the analysis of the spectrograms and more specifically, on the duration of the voice bar during /s/. The results revealed substantial variability in the realization of the /s/-voicing in many ways. Most of the tokens were fully voiced but there were a considerable number of partially voiced tokens as well as some voiceless tokens. More specifically, when /s/ was followed by an obstruent, almost 70% of the tokens were fully voiced and only 8% were voiceless. In contrast to this, when /s/ was followed by a sonorant, 53% of the tokens were partially voiced and 29% were totally unvoiced. Baltazani reports a lot of variability across speakers; some of them tended to voice partially or fully in almost all the cases, while in others an important part of the tokens was unvoiced (2006). Duration measurements showed that the biggest difference in the duration between voiced and unvoiced tokens was found when /s/ was followed by /d/ or /l/, that is, when a homorganic segment was following. This difference could be explained if we assume that "more gestural overlap is allowed for homorganic segments than for heterorganic ones" (Baltazani 2006, 10). Interestingly enough, these studies have provided contradictory results. Tserdanelis (2005) reports only fully voiced and unvoiced sibilants while in Arvaniti & Pelekanou (2002) and Baltazani (2006) a part of the tokens was partially voiced. According to Tserdanelis (2005) /s/-voicing is categorical (2005, 77), while the evidence from Arvaniti & Pelekanou (2002) and Baltazani (2006) supports the argument that it is a gradient phenomenon, therefore, a non-reliable criterion of the presence or absence of a prosodic boundary.The first thing we should notice is that all of these studies focused on /s/-voicing across word boundaries. There is no doubt that these studies offer a valuable background for further research not only by providing important results and conclusions, but also by offering a well designed

methodological pattern.

Unfortunately, none of these studies managed to provide definite answers. Tserdanelis' (2005) analysis was the only one arguing for a categorical sandhi rule, but his approach seems to be challenged by Baltazani (2006) who argues for an analysis that considers /s/-voicing to be a gradient phenomenon. Thus, both studies provide contradictory results, although they were based on experimental data, however, this is not surprising. First of all, there are a lot of parameters that may affect the outcomes of experimental research, such as speakers' variability reported by Baltazani and differences in the following consonants, since this was also reported by Baltazani as a parameter that affected /s/-voicing. This brief review of the related literature about /s/-voicing in Greek shows that more research is needed in order to obtain a clearer understanding of assimilation phenomena in Greek.

So far we have seen that /s/-voicing is a phonological phenomenon of assimilation, which is common across a number of languages. In terms of phonology this is a rule that will apply whenever the requirements, such as the appropriate segmental environment, are met. However, previous research has shown that in several studies in which /s/-voicing was examined in terms of phonetics, this categorical nature was not confirmed. On the contrary, a lot of variation was detected in the realization of voicing, both in the degree of voicing and in the ratio between voiced/voiceless tokens across speakers and segmental environments (Arvaniti and Pelekanou 2002; Baltazani 2006).

1.4 Acoustic features

So far we have discussed previous studies that aimed to investigate the realization of /s/-voicing. These studies focused on specific acoustic features in order to measure the degree of voicing of the sibilant. As we have seen in Baltazani's research (2006), periodicity in the waveform and the existence of the voice bar in the spectrogram are important cues for defining voicing in a segment, in that case in a sibilant. Phonetic studies that have focused on voice assimilation have shown that there are several other phonetic cues that can be used in order to detect voice assimilation. During our review of the literature we will focus on the voicing of fricatives and especially sibilants and we will try to identify phonetic characteristics that can be incorporated in the present study.

a) Duration Voiceless sibilants appear to be longer than their voiced counterparts. Baltazani's (2006) experiment on /s/-voicing showed that voiceless, therefore not assimilated, tokens were longer than the voiced tokens of the experiment. Similar results were found in Jansen (2007), where sibilants were measured as the second segment of two-consonant clusters. The results revealed greater duration for /s/ than for /z/ tokens.

b) Intensity Sibilant fricatives are in general characterized by high intensity because of their articulation mechanism (Toda, Maeda, and Honda 2010). Sibilants differ in the concentration of energy based on their articulatory characteristics (Ladefoged and Maddieson 1996; van de Velde and van Heuven 2011). More recently, Strycharczuk (2012) showed that fully voiced pre-sonorant fricatives have higher

intensity in low frequencies and that there is a significant negative correlation between the duration of voicing and the intensity in high frequencies.

c) Center of Gravity The center of gravity (CoG) could be described as a measure of the "spectral mean" (Anderson 2007, 4), within the duration of a specific segment. This measurement appears to be useful when studying fricatives and it has been used in a number of relevant studies (Padgett and Zygis 2003; Lee and Choi 2008; Niebuhr, Lancia, and Meunier 2008; Ahn 2011). These studies have shown differences in the CoG between different sibilants; more specifically, lower CoG values in voiced than in voiceless sibilants (Niebuhr, Lancia, and Meunier 2008) and lower CoG in [sh] than [s] sibilants (Padgett and Zygis 2003, 161). In the case of voiced and voiceless tokens the difference can be explained by the presence of the voice bar in the lower frequencies area that reduces the CoG of the voiced tokens (Niebuhr, Lancia, and Meunier 2008, 224). In the case of [sh] and [s] difference though, we can assume that differences in the articulation, such us the size of the cavity (Ahn 2011, 21) may affect the CoG.

1.5 Research approach

The phenomenon of /s/-voicing in SMG is an interesting case of the relation between phonological analysis and phonetic realization. A number of phonetic studies have shown that assimilation does not apply in all the cases and that there is a lot of variability among speakers. Furthermore, Baltazani (2006) has shown that the following consonant affects the degree in which assimilation is applied, supporting an explanation within Articulatory Phonology. Tserdanelis (2005) argues for an absolute application of /s/-voicing when there is no prosodic boundary blocking it. These results leave the question about the nature of /s/-voicing open in the sense of its phonetic realization and its phonological description.

This study however does not provide an exhaustive investigation on the acoustic characteristics of voicing assimilation in Greek. For the purposes of this experiment we maintained our focus on the appearence of the voice bar in the duration of a sibilant, following the methodology used previous studies on Greek /s/-voicing (Tserdanelis 2005; Baltazani 2006), considering this parameter as the main indicator of voicing assimilation. However, unlike Baltazani (2006) we did not approach the phenomenon categorically, that is, dividing the tokens in voiced, partially voiced and voiceless, but continuously, as a ratio of the voicing duration over the total duration of the sibilant, an approach followed by Schmidt and Willis (2011) in the case of /s/-voicing in Mexico City Spanish. This way we attempted to have a more specific look on the partially voiced tokens and how they might be affected by factors such as the following consonant. Furthermore, Baltasani (2006) focuses only on the acoustic characteristic of duration, providing results that show a higher duration in voiceless tokens. In this experiment we investigate the correlation between the voicing ratio and duration as well the intensity and the Center of Gravity of the tokens in order to examine the similarities and possible differences between the assimilated voiced sibilant and the /z/ tokens in intervocalic position that were tested as control data in this experiment.

Finally the present study does not aim at examining the phenomenon in terms of listeners' perception.

Slis and Cohen (1969) used synthetic stimuli to provide evidence supporting the role of acoustic characteristics such as the formant transitions at and the relative duration between the cosnonant and the preceding vowel in terms of perception. However the presence or absence of the voicing bar in the experimental stimuli was considered the major factor in the perception of the voiced/voiceless distinction (Slis and Cohen 1969). However, to the author's knowledge no such study has been conducted for the case of /s/-voicing in SMG. Additionally, unlike other cases of voicing, such as final voicing in English where minimal pairs have been tested perceptually in words ending with a $C_{[+voi]}$+/s/ or a /s/+$C_{[-voi]}$ cluster (Kim 2013), voiced and voiceless sibilants can only be found in minimal pairs in an intervocalic or prevocalic position.

(5) σώνει ζώνη
['soni] [zoni]

This study aims to test a number of expectations and hypotheses regarding our experimental results:

1) Based on literature, we expect a significant effect of the type of consonant on the application of /s/-voicing.
2) Between-speaker variation is expected, as it was also present in previous experiments.
3) We assume that the acoustic characteristics of assimilated tokens will be close to the acoustics of /z/ phonemes in terms of duration, CoG and intensity.
4) We will test the hypothesis that boundary depth plays a role on /s/-voicing. If /s/-voicing is only blocked by prosodic boundaries that occur between words, we would expect a higher voicing ratio in within-word clusters. Voicing assimilation in the stem or across morpheme boundaries cannot be affected by prosodic boundaries, hence we should expect a voicing ratio closer to 1.0 compared to /s/-voicing across word boundaries. In terms of Baltazani's methodology, this would mean less, or no partially voiced and voiceless tokens in within-word clusters.

2 Methodology

2.1 Experimental Design

Participants

Nine native speakers of Standard Modern Greek, between 24 and 30 years old. were recorded in a quiet room (3 males, 6 females). The speakers werer all students at the University of Leiden and have been living abroad for one year at most.

Material

Table 1: Voiced Consonants in SMG (Arvaniti 2007)

	Labial	Dental	Alveolar	Palatal	Velar
Plosive	b		d		g
Fricative	v	ð	z		
Nasal	m ɱ		n	ɲ	ŋ
Tap			r		
Approximant			l	ʎ	

Two word lists have been created containing /s/+$C_{[+voi]}$ clusters in the stem and across morpheme boundaries. These words were put in two short texts that the informants read aloud during the recording sessions (Appendix p. 37). The on-line version of the Reverse Dictionary of Modern Greek (Anastassiadis-Symeonidis 2012), which offers the ability to search for words containing specific clusters and segmental environments, was used as a tool for the creation of the word lists. To test /s/-voicing across word boundaries an additional text was created containing all the possible /s/+$C_{[+voi]}$ clusters twice. The passages had the form of journalistic articles discussing common social topics.

Finally, a block sample of [s] tokens was collected from every speaker. The specific tokens were in environments that would not cause voicing assimilation, e.g. in intervocalic position or preceding voiceless consonants. Additionally, all [z] tokens found in the second passage were also used as a sample of the voiced sibilant phoneme. Approximately 25 cases of [s] and 10 cases of [z] were sampled from each speaker.

2.2 Recording Procedure

The participants were recorded in a soundproof booth using a Sennheiser MKH416T Condenser microphone, connected to a Creative Live! 5.1 sound card using Adobe Audition 1.5 software to make a mono audio recording with an amplitude resolution of 16 bits at a 44.100-Hz sampling rate.

Every participant was given the same printed copy of the passages. The participants were asked to read all of them once and in a specific order. The first passage was a real article downloaded from a Greek news

portal. The role of this passage was to give the participants time to get used and familiar with the procedure and the environment before reading the passages that were designed for the experiment. The participants were asked to read these passages at a normal rate and to correct any speech errors by repeating specific words if they wanted to. There was no communication between the researcher and the participant during the recording. The whole procedure took approximately seven minutes per participant.

2.3 Acoustic measurements

The following acoustic measurements were obtained using Praat (Boersma and Weenink 2018):

Total Duration

The total duration for every /s/ token.

Voicing Duration

The duration of voicing for every /s/ token. First the number of voiced intervals in the /s/ sound was obtained and then the sum of their durations was calculated

$$\text{Voicing Duration} = \sum_{i=1}^{n} (t_{end} - t_{start}) \tag{1}$$

where:

n = number of intervals

t_{start} = starting time of voiced interval

t_{end} = ending time of voiced interval

Voicing Ratio

A voice/unvoiced tier was created using the PointProcess(periodic, cc) algorithm in Praat. Then the voicing ratio of every /s/ token was calculated by dividing the duration of the voice part(s) of the token by its total duration:

$$\text{Voicing Ratio} = \frac{\text{Voicing Duration}}{\text{Total Duration}} \tag{2}$$

Intensity

The mean intensity for the /s/ token in dB using the energy averaging method in Praat

CoG

The Center of Gravity for every /s/ token, in Hz using the FFT in Praat.

2.4 Statistical Analysis

The following variables were used as predictors of voicing ratio:

Following consonant

The type of the consonant following the /s/ token was used as a fixed faxtor. This variable has five levels: nasal, plosive, fricative, approximant, tap.

Boundary level

The morphological boundary between the /s/ sound and following consonant. This variable has the levels: stem, morpheme, word.

Speaker

Since speakers may have individual characteristics regarding /s/-voicing this variable was inlcuded as random effect.

Preceding Vowel

A binary variable was included to indicate the existence or absence of a preceding vowel that could cause progressive voicing to the sibilant.

3 Results

3.1 Control Data: Acoustic characteristics

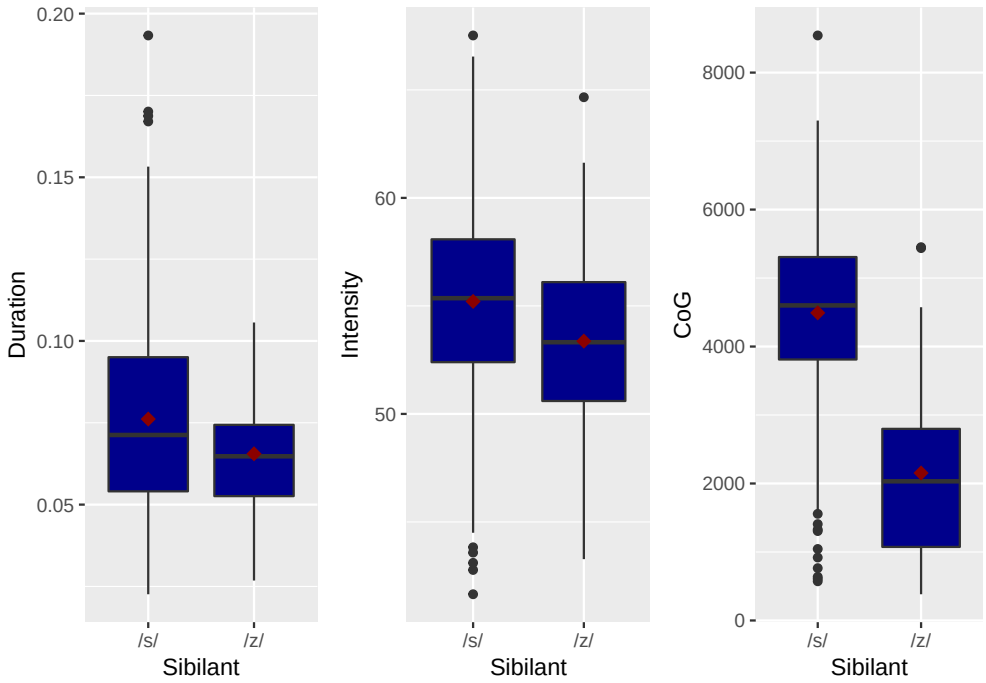

Figure 1: Duration, intensity and CoG of the voiceless and voiced sibilants

We will first explore the acoustic characteristics of the two phonemes /s/ and /z/ and we will try to understand the acoustic differences between a voiced and a voiceless sibilant.

In Figure 1 we can compare the duration, intensity and CoG of the two phonemes. The boxes represent the interquartile range, boxes margins indicate the 25th and 75th percentile and lines represent values -/+1.5 times interquartile range above and below the 25th and 75th percentile respectively. The dark line inside the box represents the median and the red point the mean. Voiceless sibilants (/s/) are characterised by slighlty increased duration and intensity. The clearest difference between the two sibilants can be found in the CoG. As we can see in Table 2, the CoG for the voiceless sibilant /s/ has a mean of 4491 Hz while the mean for the voiced sibilant /z/ is 2153 Hz.

Table 2: Descriptive statistics for duration, intensity and CoG for /s/ and /z/ phonemes

variable	group	n	mean	sd	median	min	max	range	skew	kurtosis
Duration	/s/	229.00	0.08	0.0	0.07	0.02	0.19	0.17	0.83	0.76
	/z/	68.00	0.07	0.02	0.06	0.03	0.11	0.08	0.15	-0.31
Intensity	/s/	229.00	55.21	4.80	55.36	41.65	67.52	25.87	-0.14	0.24
	/z/	68.00	53.37	4.25	53.32	43.28	64.66	21.38	0.00	-0.10
CoG	/s/	229.00	4491.97	1391.09	4600.49	572.36	8542.19	7969.83	-0.51	0.55
	/z/	68.00	2153.47	1229.62	2032.28	382.86	5450.73	5067.87	0.60	-0.21

Repeated-measures ANOVAs were ran to compare intensity, duration and CoG between the two sibilants.

Table 3: ANOVAs between sibilant and duration, intensity, CoG

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Duration	8	0.0005	0.0005	9.86	0.0138
Intensity	8	21.56	21.56	8.21	0.0210
CoG	8	25514588.26	25514588.26	93.46	0.0000

The results (Table 3) indicate a significant difference between the /s/ and /z/ phonemes in terms of duration, intensity and CoG. However, we should take into account the highly unequal sample size of the two phonemes (N(/s/) = 229, N(/z/) = 68).

3.2 Voicing Ratio

The main focus of this study is the effect of the phonological and morphological environment on the voicing ratio. In this section we will discuss the main characteristics of the voicing ratio in the data before attempting to explore any factors that might being affecting it. In the following figures we can see the histograms of the voicing ratio for both /s/ and /z/. As we can see, /z/ tokens are fully voiced as expected in most cases. However, there are a tokens where voicing is not present during the whole phoneme. On the other side, /s/ tokens have a much lower voicing ratio, closer to zero. However, /s/ tokens are spread more equally, across a range between 0-.25. This means that partial voicing is likely and present in /s/ tokens. A possible reason for this may the preceding and following vowels and/or speaker-specific characteristics in articulation. We should therefore expect that assimilated sibilants might already be partially voiced, even before the assimilation process affects them.

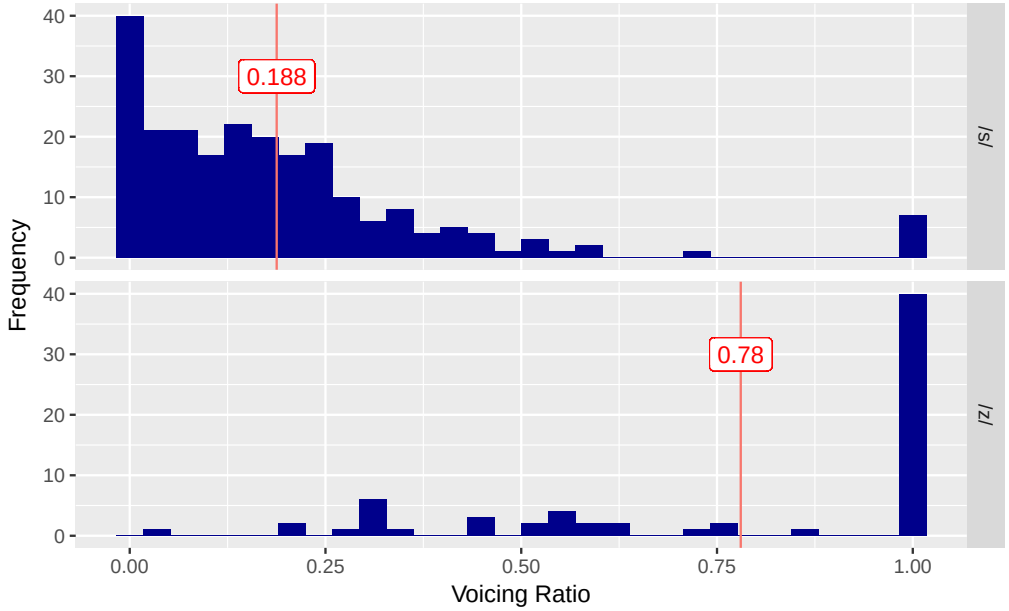

Figure 2: Voicing ratio histograms

Table 4: Descriptive statistics for voicing ratio in /s/ and /z/

Phoneme	n	mean	sd	median	min	max	range	skew	kurtosis
/s/	842	0.52	/incl0.40	0.39	0.00	1.00	1.00	0.17	-1.68
/z/	68	0.78	0.29	1.00	0.04	1.00	0.96	-0.82	-0.88

3.3 Acoustics of voicing

In this section we will examine the relationship between the three acoustic correlates, that is the duration, the mean intensity and the CoG of the sibilant and the voicing ratio of the assimilated tokens. Our hypothesis is that these acoustic correlates will reflect the degree of voicing. In order to eliminate between-speaker variation the variables were z-normalised by speaker.

First we will examine the correlations between the three acoustic correlates. As we can see in Table 5, all the acoustic correlates are positively correlated to each other and the highest correlation can be found between intensity and CoG ($r = .577, p < .01, R^2 = .346$).

Table 5: Correlation and linear regression between duration, intensity and CoG

	Dependent variable:		
	CoG_z		Intensity_z
	(1)	(2)	(3)
Intensity_z	0.588***		
Duration_z		0.219***	0.219***
Observations	613	613	613
R^2	0.346	0.048	0.048
Adjusted R^2	0.345	0.046	0.046
Residual Std. Error (df = 611)	0.739	0.892	0.909
F Statistic (df = 1; 611)	323.196***	30.739***	30.768***
Note:			*p<0.1; **p<0.05; ***p<0.01

A multiple regression was run in order to test how well can the three acoustic measures predict the voicing ratio $R^2 = .73$. Finally, independent linear regressions were conducted in order to investigate the explanatory power of voicing ratio on each of the acoustic parameters on the ratio of voicing. The results (Table 6) show significant negative correlations for all three parameters. Voicing ratio explained a significant amount of variance in CoG ($R^2 = .683, r = -0.826, p < .01$).

Table 6: Linear regressions for voicing ratio

	Dependent variable:		
	Voicing Ratio		
	(1)	(2)	(3)
CoG_z	−-0.826***		
Intensity_z		−0.350***	
Duration_z			−-0.293***
Observations	613	613	613
R^2	0.683	0.123	0.086
Adjusted R^2	0.683	0.122	0.084
Residual Std. Error (df = 611)	0.217	0.361	0.369
F Statistic (df = 1; 611)	1319***	85.68***	57.27***
Note:		*p<0.1; **p<0.05; ***p<0.01	

3.4 Between-speaker variation

Figure 3 shows differences between speakers regarding the voicing ratio. While some speakers seem to apply full voicing in most cases (speakers: 3, 6, 7), other speakers apply partial voicing much more often (1, 2, 8, 9). Therefore, there seems to be a speaker-dependent variability in the degree of voicing.

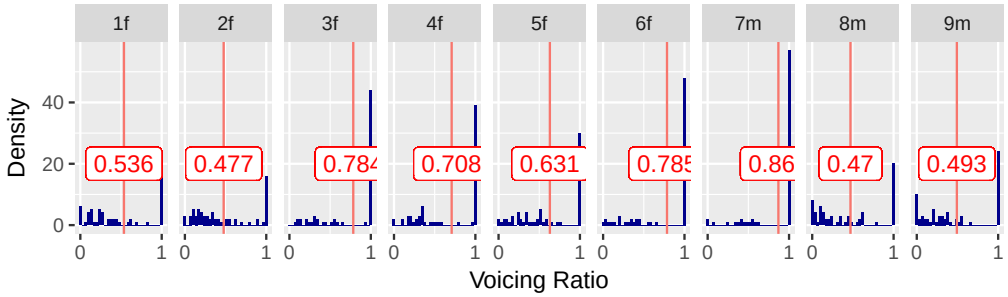

Figure 3: Voicing ratio by speaker

Figure 4 reveals between-speaker variability also in the production of /z/. It is interesting that the speakers with the highest voicing ratio, also produce /z/ fully voiced almost in all cases. Most speakers though tend to produce /z/ as partially voiced. In contrast to the, /s/ tokens are always produced voiceless or with a low voicing ratio (between 0-.25). These figures show that voicing is a process that might differ from speaker to speaker.

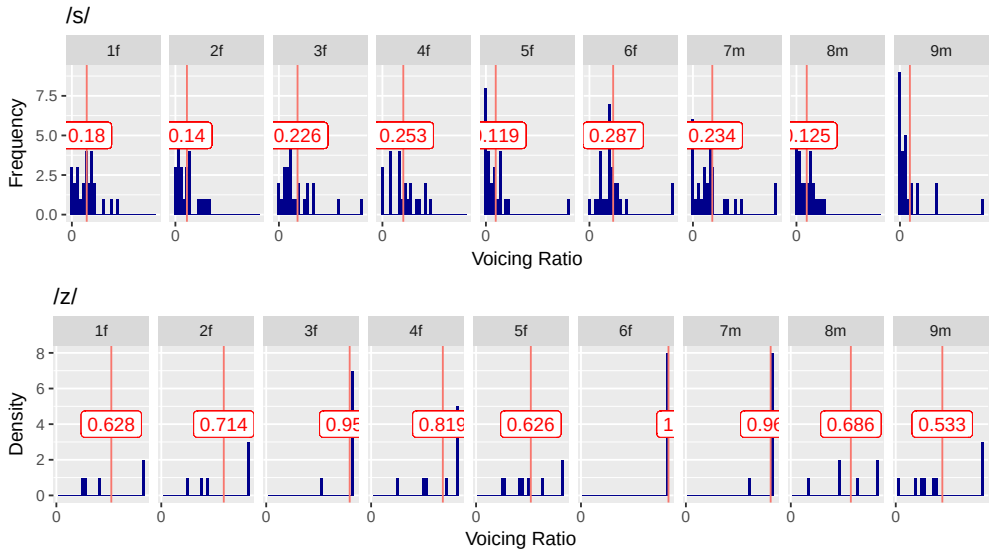

Figure 4: Voicing ratio by speaker in /s/ and /z/ phonemes

3.5 What causes /s/-voicing?

In this section we will examine the role of the morphological boundary, as well as the following consonant in /s/-voicing. The histograms show the ratio of voicing by consonant and by boundary The histograms show clear differences in the ratio between different types of consonants. Plosives,, a type of consonant that does not appear preceding a sibilant in within-word clusters, has the highest voicing ratio. Boundary depth on the other hand do not seem to affect drastically the voicing ratio. In general we observe higher probability towards the right edge of the distribution, that is, a higher probability of full voicing, with the exception of alveolar consonants. Additionally, in the Boundary Depth histograms we see a high probability of voicing ratio values around 0.25, and a decreased probability of values close to 0.75. This might partly be caused be the voicing tail from the preceding vowel. In other words, when not fully voiced, the /s/ segments are more likely to be 25% voiced rather than 50% or 75% voiced.

In order to statistically examine the effect of boundary level on /s/-voicing, a regression model with mixed effects was conducted. Since our dependent variable is a scale bounded at both ends (from 0 to 1) a beta distribution was used (Verkuilen and Smithson 2012).

As a first step we test the interaction between the type of consonant and the morphological boundary (Table 7). Speaker was used as a random effect in order to take into account between-speaker variability. The presence of a preceding vowel in the form of a binary variable was also used as a random effect. An ANOVA test was conducted between the null and the full model (Table 8) revealed no significant interaction between type of consonant and boundary depth ($p = 0.25$).

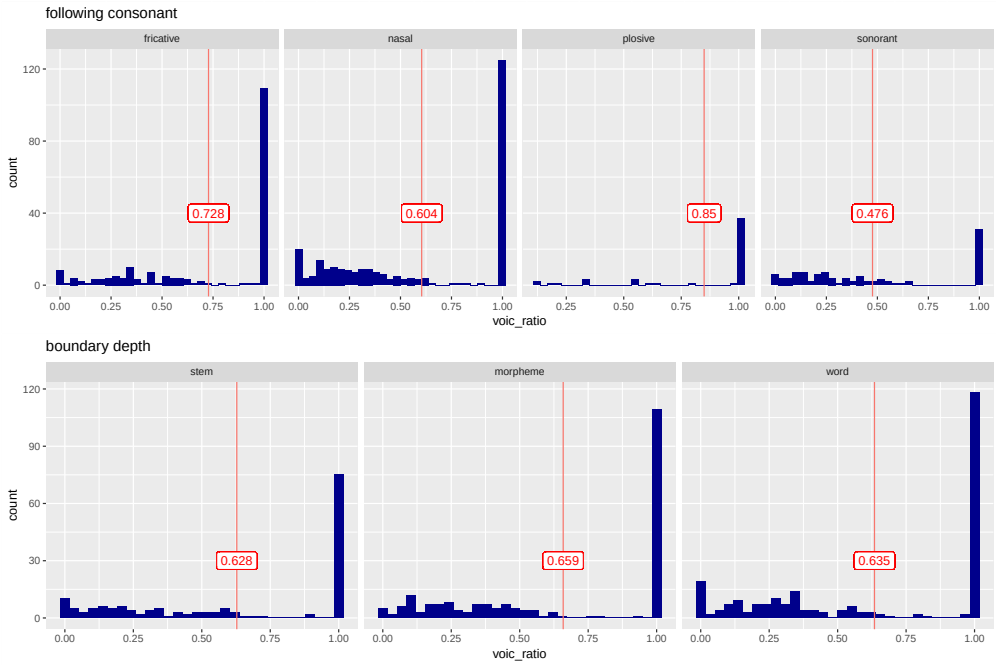

Figure 5: Histograms of the voicing ratio by type of following consonant and boundary depth

Table 7: Model - Consonant * Boundary Interaction

Model	Model Strucure
Full model	glmmadmb(voic_ratio ~ consonant * boundary + (1|speaker) + (1|vowel_bin), family="beta")
Null model	glmmadmb(voic_ratio ~ consonant + boundary + (1|speaker) + (1|vowel_bin), family="beta")

Table 8: ANOVA - Consonant * Boundary Interaction

	NoPar	LogLik	Df	Deviance	Pr(>Chi)
Null Model	7.00	617.81			
Full Model	9.00	619.20	2	2.78	0.2491

A beta regression was conducted to test the effect of boundary depth on the voicing ratio of the sibilant **??**. Speaker and the presence of a preceding vowel were introduced as random effects in the model. A one-way ANOVA between the full model and the null model (Table 10) indicates a significant effect of boundary depth on voicing ratio (p = .0317)

Table 9: Model - Voicing ratio and morphological boundary

Model	Model Strucure
Full model	glmmadmb(voic_ratio ~ consonant + boundary + (1|speaker) + (1|vowel_bin), family="beta")
Null model	glmmadmb(voic_ratio ~ consonant + (1|speaker) + (1|vowel_bin), family="beta")

Table 10: ANOVA - Voicing ratio and morphological boundary

	NoPar	LogLik	Df	Deviance	Pr(>Chi)
Null Model	7.00	1037.66			
Full Model	9.00	1041.11	2	6.90	0.0317

Finally, we also tested the effect of the type of consonant on the /s/-voicing, using again a beta regression model with mixed effects (Table 11). The ANOVA test between the two models is highly significant ($p < .000$) indicating a strong effect of the type of consonant on the voicing of the preceding sibilant (Table 12).

Table 11: Model: Voicing ratio and following consonant

Model	Model Strucure
Full model	glmmadmb(voic_ratio ~ consonant + boundary + (1|speaker) + (1|vowel_bin), family="beta")
Null model	glmmadmb(voic_ratio ~ boundary + (1|speaker) + (1|vowel_bin), family="beta")

Table 12: ANOVA: Voicing ratio and following consonant

	NoPar	LogLik	Df	Deviance	Pr(>Chi)
Null Model	6.00	1022.14			
Full Model	9.00	1041.11	3	37.94	0.0000

Bonferroni corrected pariwise comparisons were conducted (Table 13) revealed significant differences regarding the voicing ratio in most of the pairwise comparisons on types of consonants. Exceptions to that where were the *fricatives-plosives* and *nasals-sonorants* pairs. On the other hand, there are no significant differences in the pairwise comparisons of the voicing ratio between different boundaries.

Table 13: Bonferroni Pairwise Comparisons

Consonant	p-value
nasal - fricative	.0013
fricative - plosive	.1428
fricative - sonorant	< .0001
nasal - plosive	.0011
nasal - sonorant	.3886
sonorant - plosive	< .0001
Boundary	
stem - morpheme	.5678
stem - word	.6606
morpheme - word	.2218

4 Discussion

The results presented in this study indicate that the prominent factor for the realisation of /s/-voicing is the type of the following consonant. This is not new and has been demonstrated in previous studies on the phenomenon (Baltazani 2006). Voicing assimilation appears more often and at a higher degree when the sibilant precedes a fricative or plosive consonant compared to nasal voiced consonants.

However, this experiment offers some additional information. Although there is an overall significant effect of the boundary depth in which the phenomenon occurs, post-hoc analysis showed no significant effect on any of the pairwise comparisons.

In all three morphological boundaries we see a dip in the histogram, around the 0.75 margin (Figure 5). It is possible that this dip marks the difference between cases where the assimilation had been applied and cases in which it has not. Cases with a voicing ratio up to .50 could be indicative of progressive voicing caused by the preceding vowel. In these cases the first half of the sibilant is voiced and no regressive voicing from the following consonant is applied. In cases where regressive voicing is actually applied the ratio gets closer to 1.00, that is the sibilant becomes fully voiced.

Significant between-speaker variation was observed in the results. This variation is also present in the realization of the phoneme /z/ in intervocalic position. Speakers 3 and 7 apply regressive voicing in almost all the experimental tokens (Figure 3) but they also tend to produce /z/ fully voiced, unlike the rest of the speakers. Voicing ratios in /z/ phonemes for most of the speakers in the experiment ranged from 0.5 to 1, while the voicing ratio distribution in /s/ phonemes is left skewed. For speakers 3 and 7 the differentation between /s/ and /z/ is clearer as the voicing ratio distribution is strongly right skewed.

Our hypothesis regarding the effect of boundary depth predicted that voicing assimilation will occur more often in word-internal position compared to between-word boundaries. This hypothesis was not confirmed in this study. It is possible that deeper prosodic boundaries may have a clearer effect on the application of /s/-voicing, however, the design of this experiment aimed at eliminating, or at least minimising the existence of clear prosodic boundaries across word boundaries in which $/s/ + C_{[+voi]}$ clusters appear.

An additional aspect of this phenomenon is the perception of voiced/voiceless sibilants by native Greek listeners. As the results suggest, there is a wide range of values in the voicing ratio of the sibilants that occur in $/s/ + C_{[+voi]}$ clusters, based on the following consonant and the speaker. An interesting question would be whether there is a threshold in the voicing ratio for identifying a token as voiced or voiceless and whether native listeners are insensitive to differences in the voicing ratio in these clusters once this threshold has been reached.

5 Conclusion

In this study we explored the acoustic characteristics of the regressive /s/-voicing assimilation phenomenon in Standard Modern Greek. We have done so by conducting an experiment in which the voiced greek sibilant /s/ was examined in a phonological environment that causes regressive voicing, that is preceding a voiced consonant. We have tested the effect of both the type of the following consonant and the morphological boundary that follows the sibilant. Additionally we have compared the realization of voicing among the 9 speakers that took part in the experiment. We have measured the degree of voicing as a percentage of the voiced part of each token over its total duration The results show a strong consonant effect, in accordance to the literature. We have not been able to determine a significant effect of boundary depth on the applciation

of /s/-voicing. Between-speaker variability was also significant, indicating a speaker-idiosyncratic aspect of /s/-voicing. Further research could reveal the effect of voicing ratio variability on the perception of voicing assimilation.

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Appendix

Clusters within word boundaries

Table 14: Word list

Cluster	Stem-internally	Across morphemes
/s/+/v/	prezvévi	ðizvástaxtes
	amfizvitísun	prozváli
	zvísun (3)	
/s/+/ʝ		prozjíosi
/s/+/ð/		prozðiórisan (2)
/s/+/l/	slaviká	ðizliturjía
	islamikés	prozlamvánouses
/s/+/m/	kózmo (2)	θezmás (2)
	pagózmios	ðizmenís (2)
	politizmó (2)	anagazménos (3)
	zmíkrinsi	ðixazménes
	smileménes	apofasizménes
		apotelezmatiká
		zvizménos
		prosðiorizmó
/s/+/n/		ðiznóites
/s/+/r/		isroí

Text 1

Δεν υπάρχει αμφιβολία ότι η Ευρώπη βρίσκεται σε ένα σημαντικό σταυροδρόμι της ιστορίας της.Διαχρονικά η Ευρώπη αποτέλεσε πηγή εξελίξεων που άλλαξαν τον κόσμο και προσδιόρισαν αυτό που σήμερα ονομάζουμε «δυτικό» πολιτισμό.Η σημερινή κρίση όμως θα μπορούσε να δημιουργήσει νέες συνθήκες τόσο στον τρόπο ζωής μας όσο και στην κοινωνική δομή των χωρών της Ευρώπης. Για την πλειοψηφία των πολιτών οι οικονομικές πτυχές αυτής της κρίσης φαντάζουν αρκετά σύνθετες και δυσνόητες, ωστόσο όλοι αισθανόμαστε τις επιπτώσεις της στην καθημερινότητά μας και τον τρόπο με τον οποίο επηρεάζει την ποιότητα ζωής των Ευρωπαίων. Πέρα από οικονομική όμως, η κρίση αυτή μπορεί να μετατραπεί σε μια κρίση θεσμών, απειλώντας διαχρονικές αξίες τις οποίες πρεσβεύει ο σύγχρονος Ευρωπαϊκός πολιτισμός. Εάν η κρίση επιδεινωθεί είναι πιθανόν οι πολίτες να αμφισβητήσουν έντονα τη δομή της σημερινής κοινωνίας.Το πρόβλημα είναι φανερό ήδη στην Ελλάδα.Η δυσλειτουργία των θεσμών έχει προκαλέσει δυσμενείς επιπτώσεις στο αίσθημα ασφάλειας των πολιτών, την οικονομία, και τη δικαιοσύνη.Αν οι οικονομικές συνέπειες της κρίσης είναι δυσβάσταχτες για τον μέσο Έλληνα, οι αντοχές του εξαντλούνται όταν βρεθεί αναγκασμένος να συναλλαγεί με το κράτος.Οι φωνές που μιλούν για ανάγκη σμίκρυνση του κράτους συνεχώς πληθαίνουν.Το μόνο σίγουρο είναι ότι μια σειρά από μεταρρυθμίσεις είναι άμεσα απαραίτητες

Text 2

Η μεγάλη εισροή μεταναστών στην Ευρώπη αποτελεί ένα από τα πιο καυτά ζητήματα σήμερα για πολλές ευρωπαϊκές κοινωνίες.Χιλιάδες άνθρωποι είναι αναγκασμένοι να ζουν σε άθλιες συνθήκες, δημιουργώντας εικόνες «γκέτο» σε μεγάλες πόλεις.Το πρόβλημα είναι ιδιαίτερο έντονο στην Ελλάδα ωστόσο δεν αφορά τα συγκεκριμένη χώρα και μόνο.Πολλοί άνθρωποι αναγκασμένοι από τις συνθήκες ζωής ή τους πολέμους, εγκαταλείπουν τις χώρες τους και στρέφονται προς την Ευρώπη. Οι άνθρωποι αυτοί έρχονται από διαφορετικές κοινωνίες και με διαφορετικές προσλαμβάνουσες και δεν είναι σπάνιες οι περιπτώσεις στις οποίες η προσαρμογή αυτών των ανθρώπων δεν είναι ούτε ομαλή ούτε ειρηνική. Οι κοινωνίες μοιάζουν διχασμένες σε σχέση με το συγκεκριμένο θέμα ενώ οι κυβερνήσεις δεν δείχνουν αποφασισμένες ούτε ικανές να αντιμετωπίσουν το θέμα αποτελεσματικά. Ωστόσο το πρόβλημα δημιουργείται στις χώρες προέλευσης των μεταναστών ή προσφύγων πολύ πριν αγγίξει τη δική μας περιοχή.Συνεχείς πόλεμοι, οικονομική εκμετάλλευση και φτώχια είναι οι βασικοί λόγοι που οδη-

γούν τους περισσότερους από τους μετανάστες στη φυγή.Η διεθνής πολιτική των ανεπτυγμένων χωρών έχει σημαντικές ευθύνες για την άθλια κατάσταση πολλών χωρών της Ασίας και της Αφρικής.Αυτό είναι που θα πρέπει πρωτίστως να αλλάξει.Θα χρειαστεί να γίνει μεγάλη προσπάθεια ώστε να σβήσουν αυτές οι βαθιές ανισότητες που κυριαρχούν παγκοσμίως σήμερα.θα πρέπει να γίνει σκοπός των λαών του δυτικού κόσμου το να μειωθούν οι συγκρούσεις διεθνώς και να καταπολεμηθεί η πείνα και η ανέχεια που προσβάλλει πολλές περιοχές του κόσμου.Σήμερα η Ευρώπη επεκτείνει τα όρια επιρροής της.Οι σχέσεις της με το Ισραήλ, τη Ρωσία, και όλα τα Σλαβικά έθνη είναι πιο καλές από ποτέ.Οι σχέσεις της Ευρώπης με τις ισλαμικές χώρες θα έχουν αναμφισβήτητα καθοριστική σημασία και για τις δύο πλευρές στο μέλλον.Είναι στο χέρι της Ευρώπης να επιδιώξει έναν νέο προσδιορισμό των σχέσεών της με τον αναπτυσσόμενο κόσμο ξεπερνώντας ίσως αντιλήψεις σμιλεμένες σε βάθος αιώνων.Αν δεν γίνει κάτι τώρα, ίσως η προσγείωση στην πραγματικότητα να είναι αρκετά απότομη για όλους μας, Η λογική της αδιαφορίας απέναντι στα μεγάλα προβλήματα σπάνια βοηθά την κατάσταση.Στην προκειμένη περίπτωση το μόνο που θα φέρει είναι δυσμενείς επιπτώσεις στη ζωή των Ευρωπαίων πολιτών και χιλιάδες ανθρώπους στα όρια της εξαθλίωσης, σβησμένους από τον χάρτη της ανθρωπότητας.

Clusters across word boundaries

Table 15: Clusters list

Cluster	IPA	Frequency
ς + β	/s/+/v/	3
ς + γε/γι	/s/+/j	1
ς + γο/γα/γου	/s/+/ɣ/	1
ς + δ	/s/+/ð/	4
ς + λ	/s/+/l/	2
ς + μ	/s/+/m/	3
ς + ν	/s/+/n/	2
ς + ρ	/s/+/r/	2
ς + μπ	/s/+/b/	2
ς + ντ	/s/+/d/	2

Text 3

Μέσω μιας λιτής και ισορροπημένης διατροφής προσλαμβάνουμε όλα τα απαραίτητα συστατικά για τον οργανισμό μας, όπως βιταμίνες, ασβέστιο και πρωτεΐνες.Οι διατροφικές μας συνήθειες βοηθούν στη βελτίωση της λειτουργίας του οργανισμού.Η πρόσληψη ασβεστίου από τα παιδιά είναι ιδιαίτερα σημαντική καθώς κατά τη διάρκεια της βρεφικής ηλικίας διαμορφώνεται ο σκελετός.Η σωστή διατροφή, πέρα από το ότι μας γεμίζει με την απαραίτητη ενέργεια, μας δίνει και την απαραίτητη ευεξία για μια καλύτερη ποιότητα ζωής.Είναι σημαντικό λοιπόν η πολιτεία να ενημερώνει τους γονείς σχετικά με τη σημασία της διατροφής στην ανάπτυξη των παιδιών.Συχνά οι γονείς ρωτούν πώς μπορούν να κρατήσουν τα παιδιά τους μακριά από ανθυγιεινές τροφές.Σαφώς μπορούμε να εκπαιδεύσουμε τα παιδιά μας να επιλέγουν τροφές νόστιμες με λιγότερα λιπαρά.Χρειάζεται ασφαλώς χρόνος, υπομονή και φαντασία.Άλλωστε όσο και αν οι γονείς ρυθμίσουν το πρόγραμμα τους ώστε να επιβλέπουν τα παιδιά τους, πάντα θα υπάρχουν αρκετές γκρίζες ζώνες στο ημερήσιο πρόγραμμα. Λέγοντας γκρίζες ζώνες εννοούμε τις ώρες που το παιδί περνά εκτός σπιτιού π.χ.στο σχολείο, στη διάρκεια του οποίου τα παιδιά καταναλώνουν αρκετές ανθυγιεινές τροφές. Παρ΄όλα αυτά υπάρχουν πολλές τροφές που συνδυάζουν την γεύση και την καλή υγεία. Λαχανικά όπως οι φρέσκες ντομάτες βρίσκουν σχετικά εύκολα τη θέση τους στο παιδικό μενού.Μπορούμε λοιπόν να αντικαταστήσουμε για παράδειγμα το ζαμπόν με μερικές φέτες ντομάτας στο παιδικό σάντουιτς, κάνοντας ένα μικρό βήμα προς μια πιο ισορροπημένη διατροφή.Η λύση βρίσκεται στο παράδειγμα και τις συνήθειες που επικρατούν στο σπίτι.Αν οι γονείς τρέφονται ανθυγιεινά, το ίδιο θα συμβεί και με τα παιδιά.Πρωτίστως λοιπόν, πρέπει οι ίδιοι οι γονείς να βελτιώσουν τη διατροφή τους και να δώσουν αυτοί πρώτοι τα παράδειγμα στα παιδιά, τα οποία αργά ή γρήγορα θα τους μιμηθούν.